If we knew what it was we were doing, it would not be called research, would it?

-Albert Einstein

Chapter 6

Conclusion & Future Scope
6.1 Conclusion

In this thesis, effort have been made for a systematic and comprehensive study of a planar waveguide optical sensor that include design and development of a theoretical model using Simple Effective Index Method (SEIM) for the sensor structure and its application for adulteration testing of petroleum products and glucose level detection in blood plasma. At first, a detail survey on design and development of optical sensors and its appliance reported by earlier authors in the existing literature has been reviewed. A thorough study has been done on the available waveguide materials such as Silicon-On-Insulator (SOI) (silicon core), SiO₂/SiO₂-GeO₂ (Core) and SiO₂/Silicon Oxynitride (SiON core) etc. as stated in chapter-2 for fabricating the designed waveguide sensor device and then compared. Since SiO₂Nₓ waveguides permit strong confinement of light with moderately low propagation losses, high index contrast, polarization sensitiveness, chemical inertness, low material cost and its compatibility with well known conventional silicon based IC technology; we have chosen SiO₂/SiON as the waveguide material for fabricating the designed planar waveguide based optical sensor.

In these studies, at first starting from Maxwell’s equation a theoretical analysis has been carried out for wave propagation in planar waveguide sensor with Silicon Oxynitride (SiON) as the waveguide material. Using boundary condition of the proposed structure on the solution of wave equation, the dispersion relation from the wave equation of the structure has been derived for estimating the propagation constants of the modes propagated in the planar waveguide structure. Simple Effective Index method (SEIM) has been used for the modal analysis of the three dimensional (3D) planar waveguide sensors. In addition, the result obtained from simulation has shown that the measured normalized power reduces with increase in length (L) of the waveguide and this decrease slowly with length (L) for L>10 cm. The normalized
obtained from the wave equation of the designed waveguide sensor structure, the sensitivity of the proposed planar waveguide sensor has been analyzed for detection of adulteration in petroleum product. For detecting the petroleum adulteration, adulterated petroleum product was used as a sensing material which acted as the cladding layer of the planar waveguide sensor and was put inside the cylindrical enclosure (CE). It is seen that the sensor sensitivity increases slightly with increase of core refractive index ($n_c$) and independent of waveguide core thickness. This is because the sensing area does not increase with increase of $n_c$ and width of the core ($x_1$). The waveguide sensitivity is obtained as $\sim 4.1$ which is $\sim 40$ times more than that of the existing planar waveguide sensors and $\sim 20$ times more than that of asymmetric waveguide structure. The adulteration detection technique developed allows spot determination of adulteration in pure petroleum products without involving the use of chemicals.

In this work, an effort has also been made to develop a technique for rapid detection of glucose concentration in blood plasma in support of diabetes management. In the proposed technique, Lab-on-a-Chip (LOC) device platform has been integrated with plastic enclosure having optical waveguide sensor, using Poiseuille's equation of viscous flow. The technique developed has been implemented for detection of glucose level in blood plasma of alloxan-induced diabetic rat. At first, we have designed the interfacing capillary tube using the viscous flow equation, for flowing of the blood plasma into the cylindrical enclosure (CE) that holds the planar waveguide sensor inside. Using this same principle, the cylindrical length has also been designed to make the viscous force push the blood plasma to get the CE filled with it. It is seen from the theoretical results, that for different waveguide core thickness the measured normalized power decreases with increase of the waveguide length and this becomes almost constant at length ($L$) $50,000 \mu m$ which is same as that obtained from interfacing tube design. So the waveguide of core width 50 $\mu m$ and length $50,000 \mu m$ have been fabricated for the use in detection of glucose concentration in blood plasma. The detection time ($t_D$) has been estimated that comprises of separation time ($t_{sep}$), propagation time, $t_p$, refilling time, $t_r$, and the time required by the detector to give the response. It is found that the detection time is $\sim 25.85$ seconds. The sample volume of the sensor was set at 0.141 ml. This has been calculated using inside volume of PCE.
6.2 Future Prospect

As future prospects an attempt can be made to apply the fabricated integrated optical planar waveguide sensor for online monitoring of adulterated petroleum products in refinery during the fractional distillation process. Such a sensor which requires very minimal sample volume - 0.25 ml for its adulteration detection and does not involve other chemicals for its adulteration detection would help to ensure the purity of the product yielding better accuracy. This technique can be used as an online diagnostic tool for detecting glucose level in blood plasma due to its rapid detection capability, and requirement of minimal sample volume. Also, as future scope, this sensor can be extended for rapid testing of bacteria colony, detection of arsenic content in water owing to high sensitivity, high accuracy and rapid detection capability.

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